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Tilt-Rotor Blade-Vortex Interaction Noise

Final Report

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Summary of Research

With increased use of helicopters in military and commercial operations, the impact of rotor noise on the environment has become an important issue for communities' acceptance of helicopters. Of the many rotor noise generating mechanisms, blade-vortex interaction (BVI) noise is considered one of the most disturbing because of its impulsive nature. Our research on blade-vortex interaction noise generation and directionality concentrated on acquiring a physical understanding and predictive ability for BVI noise mechanisms. Our approach was to resolve the evolution of the radiated noise due to the interaction of rotor wake with a rotor blade. Two important BVI noise parameters were identified. First, the **impulse factor** which governs the intensity of the BVI noise impulse at the source; and second, the **trace Mach number** which prescribes the primary direction in which BVI noise is radiated. It was found that proper use of these BVI parameters could provide a time-efficient prediction of the intensity and directivity of radiated BVI noise levels.

The impulse factor was found to be an important parameter governing the noise intensity of blade-vortex interactions (Sim and George, 1995). Derived from first principles, this parameter characterizes the impulsiveness of the passage of the BVI. The impulse factor determines the temporal variation of the fluctuating forces induced on the rotor blades which ultimately results in noise radiating away from the rotor into the far-field. It was found that the presence of the parameter of oblique BVI angle, embedded within the impulse factor, shows that BVI noise strength is highly sensitive to the orientation of the vortex with respect to the rotor blade. Other factors that are significant includes the BVI miss distance and the local blade velocity at the location where and when the interaction occurs. With the use of this impulse factor, blade-vortex interactions that result in high radiated noise levels can be easily identified.

Our research had also established the Trace Mach number as an important parameter governing the directionality of radiated BVI noise (Sim, George and Yen, 1995). Blade-vortex interactions with supersonic trace Mach numbers were found to generate highly-directional **Mach cone noise wavefronts**. When these Mach cone noise wavefronts are

propagated into the far-field, they are responsible for introducing additional directivity effects in addition to the classic unsteady lift dipole noise radiation. The directionality of these Mach cone noise wavefronts can be efficiently predicted using the **radiation cone analysis**. Furthermore, these Mach cone noise wavefronts can intersect each other, resulting in isolated high noise regions, known as **radiation cone caustics**. These caustics are very useful in explaining zones of intense sound pressure level measured in BVI noise experiments. With these new methodologies, the directivity of BVI noise and the variation in radiated noise patterns due to changing rotor operating parameters can be readily predicted and explained. These methods were applied to the BO-105 rotor and the JVX tilt-rotor to explain and identify the principal causes for the radiated blade-vortex interaction noise directivity.

Further BVI noise directivity studies (Sim and George, 1996) had indicated, for the first time, a variation of the BVI noise directivity with observer distance, and also the inadequacy of applying the simple inverse square law to extrapolate near-field wind tunnel BVI noise measurements to far-field BVI noise predictions. The departure of BVI noise radiation/propagation from classical spherical noise propagation stems from the focusing and de-focusing effects of Mach cone noise wavefronts in certain directions especially in the near-field. These effects can be predicted by the trace Mach number /radiation cone methods. These findings have obvious consequences for future analyses of BVI acoustic data, particularly in the extrapolation of far-field noise levels from measured near-field data.

A detailed description of the different concepts, methodologies and results of this research are documented in the Cornell University Ph.D. dissertation by Ben Wel-C. Sim. The dissertation has been submitted to NASA for consideration for publication as a Contractor Report.

Acknowledgment

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Publications

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